A THz Dielectric Lens Antenna

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***Abstract*— In this paper, a dielectric extended hemispherical lens antenna is presented. The antenna has been designed to produce highly directive beams at low THz frequencies. The feeding mechanism is a standard WR-3 rectangular waveguide fitted at the bottom of lens. The antenna is suitable for newly developed waveguide-based automotive radar and communications systems. The initial geometry has been based on ray optics and has then been optimized using full wave simulations (CST Microwave Studio^{TM}). Various dielectric materials have been considered and rexolite (ε_r=2.53) has been chosen for the particular design. The antenna's central frequency is 286 GHz with a maximum gain of 38.4 dBi and a 3dB bandwidth of around 40GHz.**

Keywords*— *Lens antenna, terahertz, automotive radar applications

I. Introduction

The TeraHertz (THz) region has attracted significant research interest over the past few years since it offers new opportunities for communications [1], sensing and imaging applications [2]. Current demands in automotive radar [3] and communication applications include high-resolution imaging, propagation through adverse environments with low signal attenuation and compact low-cost systems.

To satisfy these demands, highly directive antennas are needed. Current solutions in the submillimeter-wave band include horn and lens antennas. Various implementations of lens antennas have been reported operating at millimeter-wave [4] and submillimeter-wave bands [5-7] showing promising results. However, efficient illumination of lenses has been a challenge. Feeding techniques that have been employed thus far include dual slots and irises [8] as well as more broadband primary sources such as log-spiral and log-periodic [5-7]. However, these broadband solutions are not compatible with waveguide based systems.

In this contribution, a lens antenna is proposed, directly fed by an open-ended waveguide as a primary source. In this context, a dielectric extended hemispherical lens type has been chosen to enable integration with the feeding source. A range of dielectric materials with different electrical and mechanical properties have been considered. The proposed antenna achieves high gain and wide bandwidth performance which addresses the requirements of applications such as future THz communication systems and high resolution automotive radar systems. Moreover, the antenna is compatible for direct integration with currently developed waveguide based communication and radar systems.

II. Antenna Design

The schematic of the proposed antenna configuration is shown in Fig.1. The structure is formed by a hemisphere of diameter D=40mm and a cylindrical extension layer below it with the same diameter and length L=18mm. The dielectric material is rexolite with ε_r=2.53 and tanδ from 15×10^{-4} to 40×10^{-4} at 120-550GHz. The lens shape has been chosen to allow integration of the feed antenna. The latter, is a WR-3 rectangular open-ended waveguide with aperture dimensions 0.8636mm and 0.4318mm.

As explained in [5], extended hemispherical lenses can be approximated with elliptical lenses. Thus, the length of the extension layer can be calculated using the defining equation for an ellipse such that the focal point lies at the bottom of the layer. This geometrical optics approach gives an initial estimation of the focal distance (length of the extension layer). Subsequently, an optimization of the dimensions D and L is carried out in CST Microwave Studio^{TM}, taking into account the effect of the primary source pattern.

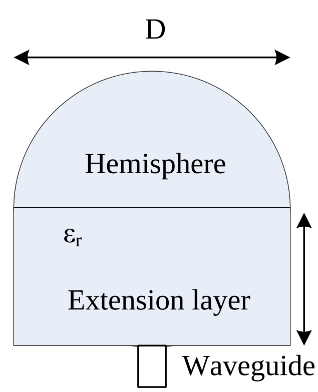

Fig. 1. Schematic of the proposed extended hemispherical dielectric lens antenna.

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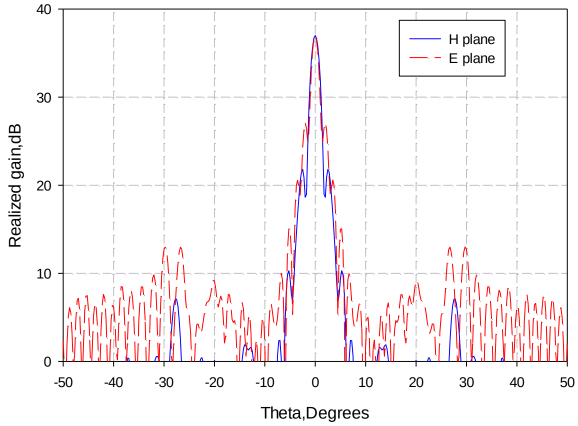
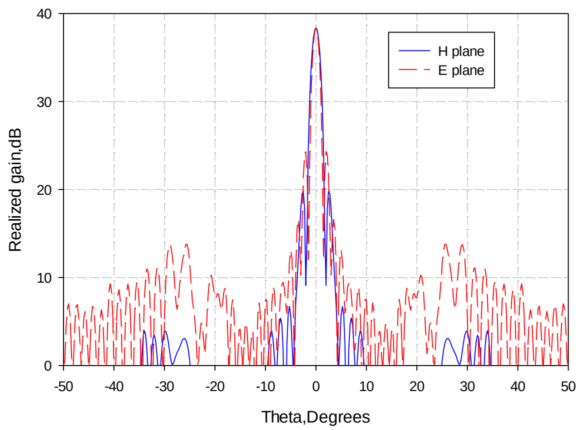
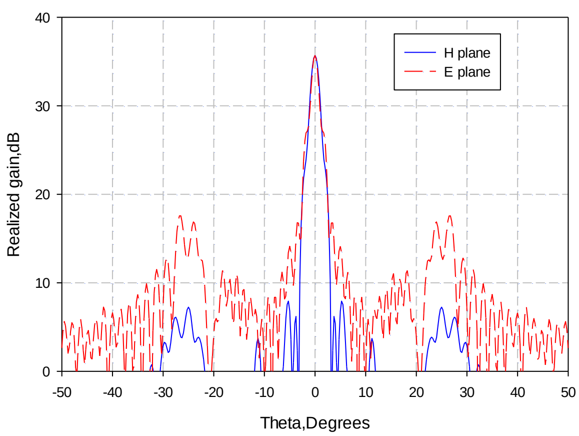


(a)



(b)



(c)

Fig. 2. H and E-plane radiation patterns for rexolite lens antenna at (a) f=275GHz, (b) f=286GHz and (c) f=305GHz.

A maximum realized gain of 38.4dB at 286GHz has been obtained with 40GHz 3dB bandwidth (14%). The matching over the operating bandwidth is below −10dB. The radiation patterns at three different frequencies are shown in Fig.2. It can be observed that the achieved 3dB beamwidths are 1.3^o and 1.6^o for E-plane and H-plane respectively. Due to the nature of the extended lens design sidelobes appear at higher angles (>20deg) but the SLL remains below -18dB.

III. Fabrication

As mentioned in the introduction, various dielectric lenses (Teflon, Rexolite, PEEK etc.) have been considered which exhibit different mechanical properties. Among these, the material for the final antenna prototype will be selected subject to the best performance and mechanical stability. The prototype will be fabricated using facilities located at the University of Birmingham. CNC machining will be used for our proposed design.

IV. Conclusions

A highly directive lens antenna operating at low THz frequencies has been proposed, with an integrated open-ended waveguide primary source. The design of the extended hemispherical lens has been based on ray optics and full wave simulations (CST Microwave Studio™). Simulated results have been presented showing a maximum gain of 38.4 dBi at 286GHz with a 3dB bandwidth of around 40GHz. The achieved beamwidths (well below 2^o) show that the antenna can be incorporated to obtain a high-resolution imaging system. The final prototype will be measured and results will be presented at the conference.

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